Surface Characteristics of Metal Fuel Rod Prepared by Using Quartz and Graphite Molds

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Introduction

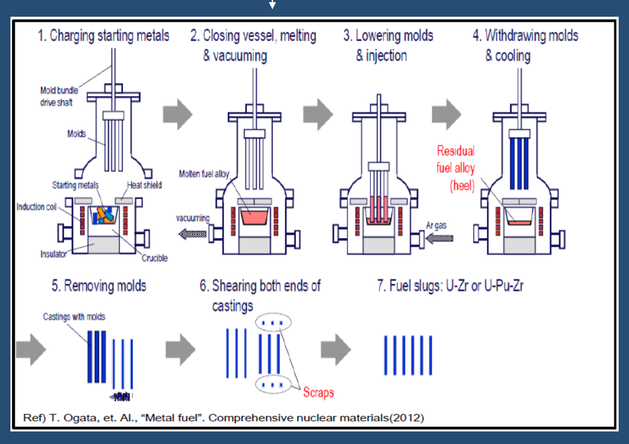
In the production of metal fuel rod with U-Zr as a basic composition, manufacturing methods are selected according to the characteristics of each country taking into consideration the advantages and disadvantages of each casting method [1-3]. The metal fuel fabrication is progress in which raw materials are melted in a crucible with high-temperature vacuum atmosphere, this melt is injected into a casting mold, cooled in a furnace, and then withdrawn from the furnace. In this study, quartz and graphite molds were manufactured as molds used in the fabrication of metal fuel rod, and a metal fuel having the composition of U-10Zr-5RE's was prepared by using them. And the reaction characteristics on the surface of the prepared metal fuel rods was observed and analyzed.

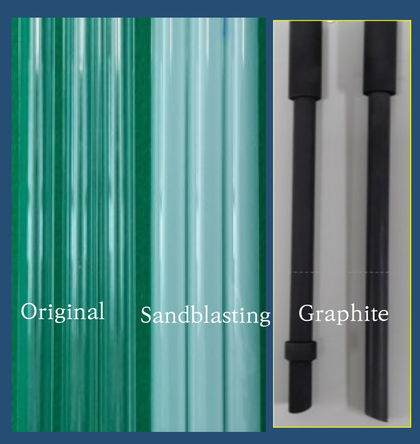
Experimental & Analysis

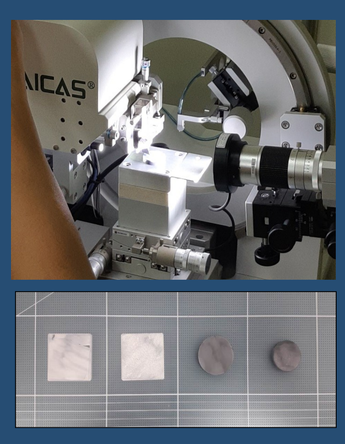
1. Melting and charging molds : starting metals and mold insertion
2. Vacuum and heating : 10^{-3} torr, Ar atmosphere, ~1500℃
3. Mold* lowering and injection : pressurizing for injection casting in mold
4. Mold withdrawing and cooling : Ar atmosphere
5. Removing mold and shearing both end, inspection, and QC/QA

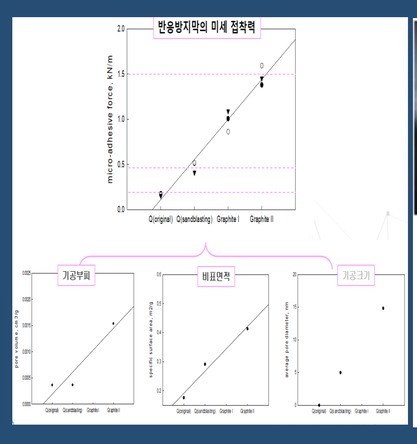
mold* : Graphite (5.6 Φmm X 300mm), inner surface : Y_2O_3 (ZrO_2)slurry coating

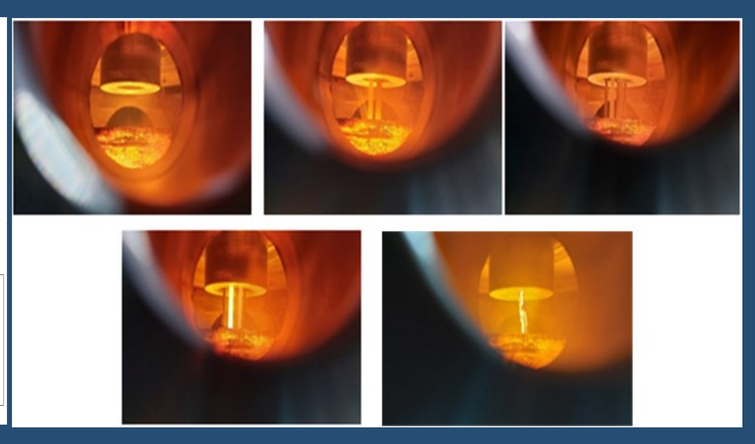
T. Ogata, et al., "Metal fuel", Comprehensive Nuclear Materials (2012)





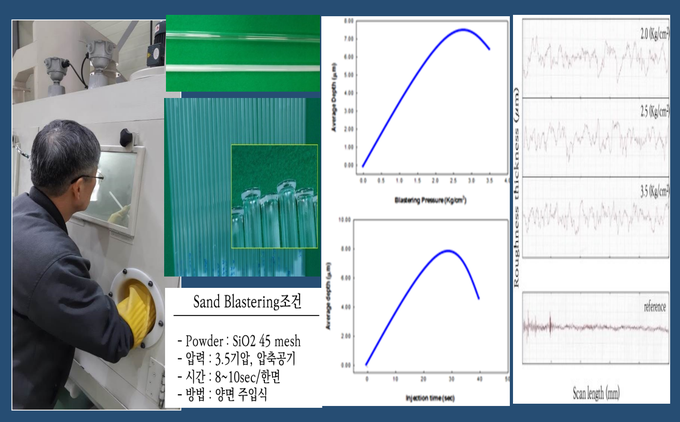






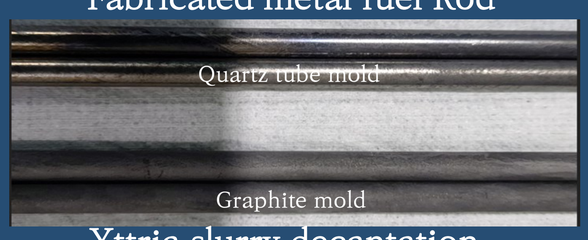
Mold Treatment and Surface Characteristics of Fabricated-Rod

Surface roughness of sandblasted quartz

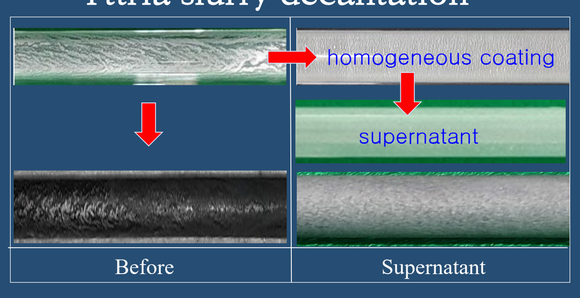


Y_2O_3 (or ZrO_2)slurry Coating

Fabricated metal fuel Rod



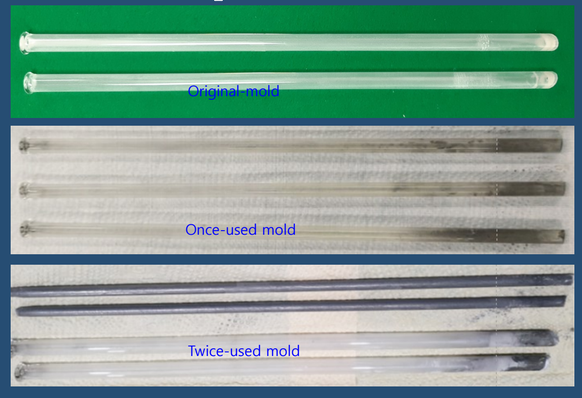
Yttria slurry decantation



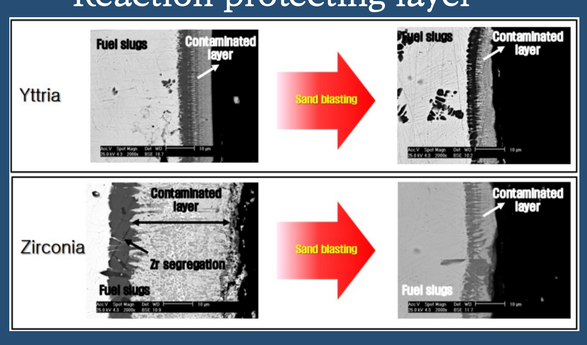
Micro-adhesive force of coating layer

		Original Quartz	Sandblastered Quartz	Graphite I	Graphite II
Micro-adhesive force, kN/m		0.1650	0.4800	0.9860	1.4780
Specific surface area, (BET), m^2/g		0.1716	0.2910	-	0.4132
Porosity	volume, cm^3/g	0.000358	0.000361	-	0.001531
	size(ave), nm	-	4.98	-	14.82

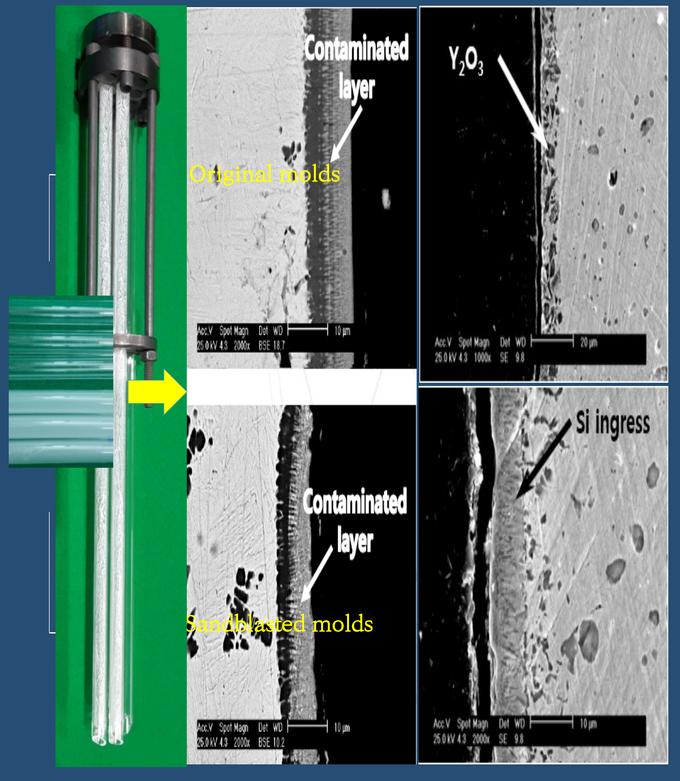
Re-use of quartz mold & Fuel rod



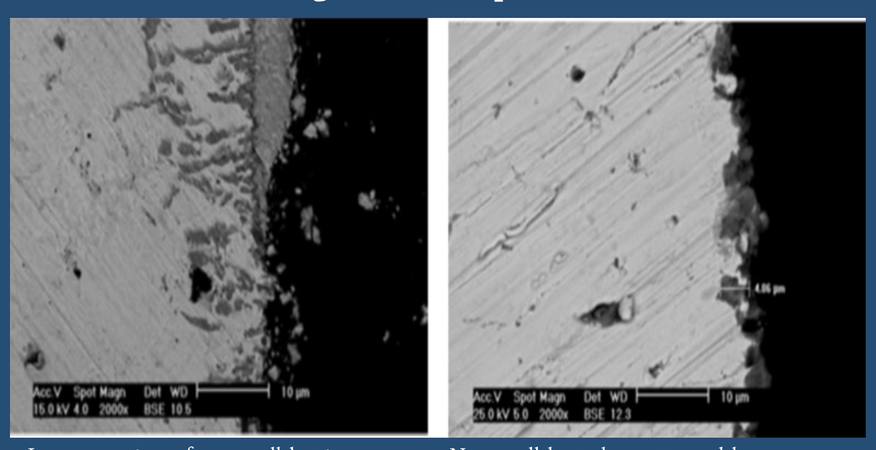
Reaction protecting layer



Surface treated quartz mold/Si ingress



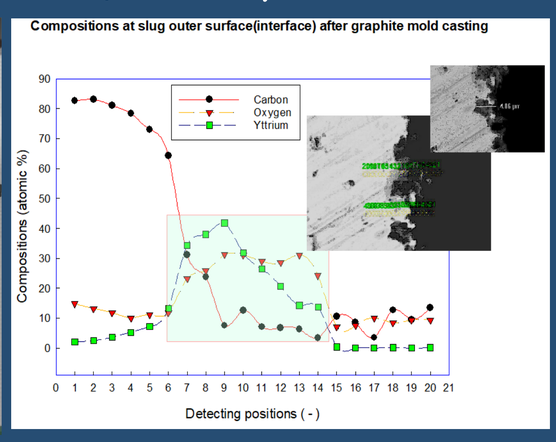
Sandblasting effect of quartz mold



Inner coating after sandblasting

No sandblasted quartz mold

SEM/EDS analysis results



The concentration of Y,C,O elements were detected relatively higher

Chemical analysis result

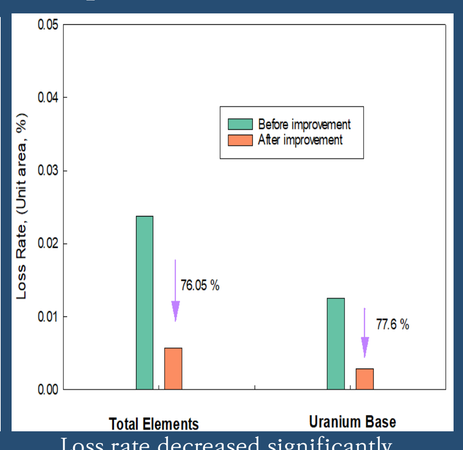
unit : wt%, (-) : < 50μg/g

		Original						Sandblastered					Graphite	
		Q-1	Q-2	Q-3	Q-4	Q-5	Ave.	S-1	S-2*	S-3	S-4	Ave.	1차	2차
U	상	-	-	-	-	0.01		-	-	-	-		-	
	중	-	0.01	-	-	0.01		-	-	-	-		-	
	하	0.04	0.02	0.02	0.02	0.01		0.06	10.6	-	-		11.6	
Zr	상	-	-	-	0.05	0.01		-	-	-	-		-	
	중	-	-	-	0.01	0.03		-	-	-	-		-	
	하	-	-	-	-	0.01		0.02	1.8	-	-		1.7	
RE's (Nd, Pr, Ce, La)	상	-	-	-	-	-		0.01	-	-	-		-	
	중	-	-	-	-	0.02		-	-	-	-		-	
	하	0.02	0.04	0.02	0.01	-		-	1.66	0.01	-		0.6	
Y	상	0.03	0.02	-	-	0.01		0.34	0.45	0.30	0.30		0.03	
	중	0.03	0.01	-	-	0.51		0.01	0.01	0.01	0.13		0.13	
	하	0.02	0.01	0.01	-	-		0.02	0.02	0.30	0.01		0.13	

S-2* : 고온실험 시편

Chemical analysis result of used quartz mold

Improvement of loss rate



Loss rate decreased significantly after surface treatment

Conclusions

The yttria slurry solution used as a reaction barrier was replaced with yttria spray aerosol and applied to quartz and graphite molds to manufacture metal fuel rod. After manufacturing the metal fuel rod, it was easier to separate the metal fuel rods and recycle them. U-10Zr-3RE composition showed the possibility of reuse for coating the inside of the quartz tube with spray coating solution about three times, while graphite molds were separable, but natural separation was difficult because the graphite-type geometries were slightly different from quartz molding. For graphite molds, further research on inner flatness improvement and prevention of leakage at prefabricated connections will be needed.

References

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- R.S.Fielding, J.Crapps, C.Unal, J.R.Kennedy, Metallic Fuel Casting Development and Parameter Optimization Simulations, INL/Con-12-26868 (2013).
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